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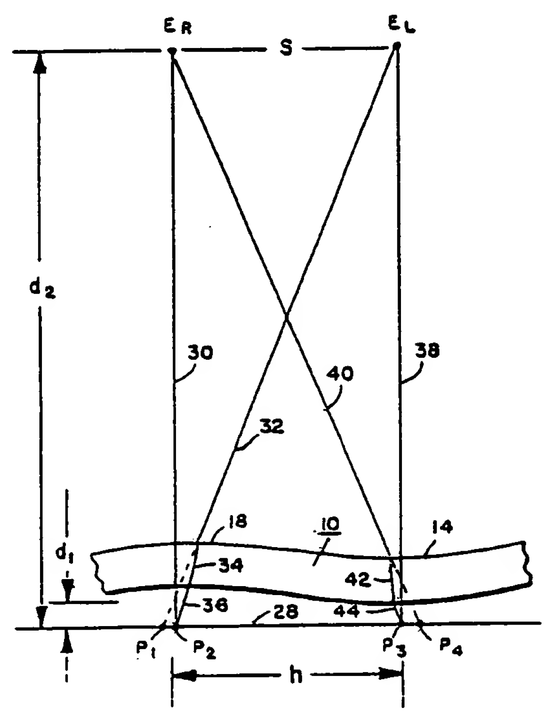
(57) Abstract

The appearance of depth in a two-dimensional image on a television screen or the like is achieved by optical bending means positioned between the image plane and the observer. The optical bending means produces a horizontal shift of points in the image such that the left and right eyes of the observer see a different spacing between pairs of points. The optical bending means can be in the form of a transparent undulating sheet (10), or can be in the form of undulations (46) incorporated in the envelope of a television tube (5). It is positioned sufficiently close to the image plane that any pair of rays diverging from any point and striking the bending means continue to diverge.



Description

Image Enhancement

Background of the Invention

This invention relates to viewing systems, and in particular to an improved viewing system for producing a simulation of depth in substantially two-dimensional visual images such as television images. The invention also relates to improvements in viewing systems for improving clarity and color rendition in such two-dimensional images.

Conventional systems for producing the appearance of depth in two-dimensional images incorporate depth information in the image itself, and provide special viewing means for utilizing the depth information. For example, in the now obsolete "3-D" motion pictures, the image displayed on the motion picture screen was actually two superimposed images which were separated by means of polarizers or colored filters. The polarizers or colored filters were incorporated in special glasses or viewers provided to the theater patron so that one eye of the patron would perceive one of the two images, and the other eye would perceive the other of the two images.

Various unconventional attempts have been made in the past to produce the simulation of depth in the viewing of two-dimensional images containing no special

placement of the substantially vertical parallel lines in front of and spaced apart from the plane of the picture presentation.

Another system for depth simulation was described by H. M. Muncheryan in his U. S. patent 2,986,969, dated June 6, 1961. Muncheryan described a binocular device having a pair of relatively rotatable polarizers in each eyepiece. Depth simulation was achieved by rotating the plane of polarization of one polarizing lens with respect to the other in one eyepiece until objects viewed have obtained apparent curvatures and depths. This effect is said to be more prominent in the angular range of 30 to 50 degrees between the polarization axes of the two polarizing elements. After the polarizers in one eyepiece are adjusted, the polarizing lens of the other eyepiece is rotated until the transmitted light intensity through that eyepiece is comfortable to the eye.

Another optical aid for simulating depth in two-dimensional images such as screen projections, drawings and photographs, was described by A. Ames, Jr. in U. S. patent 1,636,450, dated July 19, 1927. Ames used a pair of eyeglasses having a system of prisms and lenses which eliminated actual perceptive sensations. The system blurred the image seen by one eye, preferably by means of a cylindrical lens which blurs only vertical lines, leaving horizontal lines sharp. The theory of operation, as explained by Ames, is that the system of prisms and lenses causes the position of the picture in space to be indeterminate. The system of prisms and lenses causes both eyes to be relaxed in convergence and in their accommodations. The eyes are

In all of the foregoing viewing systems of the prior art, a simulated three-dimensional effect is achieved at the expense of image quality. That is, each system of the prior art either partially obscures the image or produces a blurring of visual information. In the former case there is at least a loss of light from the picture, and the loss of light may be accompanied by a loss of picture information. In the latter case, blurring of visual information has a tendency to cause eyestrain, and to make viewing for extended periods of time somewhat unpleasant. Nevertheless, apparently obscuration and/or blurring have been considered essential heretofore in the production of three-dimensional effects from conventional two-dimensional images.

Summary of the Invention

The principal object of this invention is to provide a simple viewing system for depth simulation in which obscuration of picture information is avoided, and in which there is no blurring of visual information. It is also an object of the invention to produce depth simulation in the viewing of two-dimensional images without the need for special eyeglasses or binoculars. Still another object of the invention is to provide a viewing system for improving image clarity and color rendition in addition to providing depth simulation.

In accordance with the invention, the foregoing objects are achieved by the use of optical bending means, located in a path through which the two-dimensional image is viewed by an observer, for selectively bending light rays extending from the image plane to the eyes of the observer so that, for substantially any two horizontally spaced points in the image plane, the left and right eyes of the observer perceive a different

sheet. The magnification (or reduction) of any area in the image plane is only about 5% or less; hence little if any distortion is evident to the average observer.

The operation of the viewing system in accordance with the invention involves the optical shifting of the horizontal placement of points in the two-dimensional image so that the eyes of the observer perceive different spacings between pairs of points. The horizontal shift of the placement of points in the two-dimensional image produces a slight but unobjectionable distortion characterized by a difference in the spacing between points as observed through the right and left eyes of the observer. These differences in spacing produce the sensation of depth, and the perceived depths of the various objects in the two-dimensional image arise from visual clues such as the relative sizes of objects, shadows and the obscuration of farther objects by nearer objects.

The optical bending means neither masks the picture nor diminishes the transmission of light from the picture to the observer. Thus, there is no obscuration of picture information. The optical bending means is designed to allow both eyes to perceive the same overall image size. Consequently there is no blurring of picture information in either eye by reason of differential magnification. Blurring by reason of secondary or "ghost" images is avoided by positioning the optical bending means in relation to the positions of the image plane and the observer so that rays from any point on the image plane diverge in the space between the optical bending means and the observer. Since the observer views any given small area through less than

Detailed Description

In one embodiment of the invention, a transparent sheet having substantially uniform undulating horizontal cross-sections is positioned in the path through which the two-dimensional image is viewed by the observer. Figure 1 shows a suitable transparent undulating sheet 10, preferably made from an acrylic polymer such as poly(methyl methacrylate), or a similar transparent material having a refractive index substantially higher than that of air. A series of undulations is formed in sheet 10 comprising alternating ridges and valleys which extend in the vertical direction. The valleys are indicated at 12 and 14, and the ridges are indicated at 16, 18, and 20. In the case of polycarbonates, poly(methyl mathacrylate), and other thermoplastic material, the undulations can be readily formed by the application of heat using electrically heated strips. A typical undulating sheet of the type shown in Figure 1 is 13 mm. in thickness. The depth of the valleys, measured from the peaks in the direction perpendicular to the sheet is typically 0.8 mm., and the distance betweent the tops of the peaks and the bottoms of the adjacent valleys, measured in the direction parallel to the sheet, is approximately 30 mm.

Preferably, the undulations are approximately sinusoidal. However, they may vary from an exact sinusoidal configuration. For example, they may be in the form of circular arcs. The undulations should be smooth so that the surfaces of the sheet do not at any point exceed the critical angle with respect to the paths of light rays passing through the sheet, thereby causing reflections. The smoothness of the undulations is also important to the avoidance of secondary images.

The faces of the sheet are substantially straight in the vertical direction. Hence, the horizontal cross-sections of the sheet are substantially uniform. While uniformity of the horizontal cross-sections is

in its correct position The left eye E_L, however, views point P_2 through light paths 32, 34, and 36 as as result of refraction in the transparent sheet. Consequently, point P_2 is seen by the left eye E_L at the position of point P_1, which (from the observer's standpoint) is located to the right of point P_2.

The left eye E_L views point P_3 directly and without refraction through light path 38. The right eye E_R, however, views point P_3 through light paths 40, 42, and 44 as a result of refraction. Consequently, the right eye E_R views point P_3 at the point of P_4, which is displaced to the left of position P_3.

The distance between P_1 and P_3 is slightly less than the distance from P_2 to P_4. Therefore, the right eye perceives a greater distance between the two points than does the left eye.

The undulations in sheet 10 cause the eyes of the observer to observe different distances between laterally spaced points except in the relatively few instances where symmetry causes pairs of points to be perceived at the same lateral spacing by both eyes. Consequently, for substantially any two horizontally spaced points in the image on television screen 28, the left and right eyes of the observer percieve a different horizontal spacing between the points. The resultant slight distortion caused by the interposition of undulating sheet 10 between the image and the observer is unobjectionable, and is apparently compensated for in the brain of the observer with the result that the observer receives the impression of depth in the image. The relative depths of the various components of the image are apparently determined by the observer automatically by taking into account his experiences in the real three-dimensional world. The observer automatically takes into account visual clues such as,

undulations can be decreased, and the thickness and distance from the screen can both be altered to produce the same results.

The depth of the undulations, the index of refraction, and the distance between the undulating sheet and the television screen also determine the maximum viewing angle. The maximum viewing angle is the horizontal angle through which the image may be viewed without the appearance of gaps resulting from interior reflections of light in the undulating sheet. These gaps would appear where the observer attempts to view a point on the image through a path such that the light ray from the point strikes the front surface of the undulating sheet at an angle of incidence exceeding the critical angle, i.e. that angle at which total reflection occurs. For a given sheet the viewing angle decreases as the depth of the undulations increases; it decreases with distance between the undulating sheet and the television screen; and it decreases with increases in the index of refraction of the undulating sheet material. Preferably, the viewing angle is at least 120°, measured from one extreme position of the viewer to the other extreme position. For a given undulating sheet, the range of the viewing angle can be readily adjusted by adjusting the distance between the sheet and the television screen.

The dimensions of sheet 10 and its proximity to the image plane at screen 28 are also important from the standpoint of eliminating

The peaks in an undulating sheet act as relatively weak lenses and are generally subject to the same effect unless the undulating sheet is of uniform thickness. Thus, if an undulating transparent sheet of non-uniform thickness, and having a given set of parameters, is positioned too far from the image plane, at least some rays emanating from a point on the image plane will tend to reconverge on the opposite side of the undulating sheet. If the observer is located behind the point of reconvergence, he will see a series of alternating erect and inverted images. If the observer is located in front of the point of reconvergence, or if the object is at the focal point, the image will be partially blurred.

With the viewing system in accordance with the invention, a three-dimensional effect can be produced, while retaining a sharp picture image by positioning the undulating sheet sufficiently close to the image plane that substantially any two rays emanating from any point on the image plane and passing through the undulating sheet are diverging. In this way, the image can be seen clearly without the need for the observer to wear special corrective glasses.

Preferably, the undulating sheet is smooth (i.e. free of sharp bends) in which event it can be spaced some distance away from the image plane without causing blurring. If sharper bends are present in the sheet, it is necessary to position the sheet very close to the image plane. In the case of an undulating sheet having extremely sharp bends, it may be impossible in practice to bring it sufficiently close to the image plane to achieve divergence of substantially all points in the image plane.

and the low points of adjacent valleys such that h is at least approximately ten times $\frac{sd_1}{d_2}$. The invention relies upon the fact that, even though most points are shifted in the same direction, they are shifted by different amounts for the two eyes of the observer.

In a typical system using a small screen television d_1 is 13 mm., d_2 is 750 mm., and h is 30 mm. s is assumed to be 65 mm. Thus h is approximately twenty six times $\frac{sd_1}{d_2}$.

For a large screen television, d_1 might be 63 mm. and d_2 might be 1500 mm. A typical value for h would be 63 mm. Here h would be approximately twenty three times $\frac{sd_1}{d_2}$.

Finally, focal length is an important parameter, since it is necessary to avoid localized distortion of small areas due to excessive magnification or reduction by lens effect of the undulations. In accordance with the invention the minimum focal length for the undulating screen is preferably at least approximately 400 mm., as shorter focal lengths would tend to produce readily perceptible distortion of the image.

The optical bending means can be built into a television tube, as illustrated in Figure 4, in which a series of vertically extending undulations 46 is formed in screen 48, which is part of the envelope of television tube 50. The interior side of screen 48 is provided with a phosphor coating 52, and is curved in the conventional manner so that it forms what is essentially an image "plane". The glass of screen 48 varies in thickness by reason of the undulations 46 on its outer

CLAIMS

1. A method of viewing a substantially two-dimensional visual image in an image plane (28) comprising the steps of: locating optical bending means in a path through which said image is viewed by an observer at a position between said image plane and said observer such that any two rays emanating from substantially any point on said image plane pass through said optical bending means and diverge in the space between said observer and said bending means; maintaining substantially the same perceived overall image size for both the eyes of the observer with said optical bending means; and selectively bending light rays extending from said image plane to the eyes of the observer, using said optical bending means, so that, for substantially any two horizontally spaced points in the image plane, the left and right eyes of the observer perceive a different horizontal spacing between said points; in which said selective bending step is carried out by optical bending means in the form of a transparent sheet (10) having a refractive index higher than that of air and having undulating horizontal cross-sections, and in which the distance h between the high points of the peaks (18) and the low points of the adjacent valleys (14) of the undulations is at least approximately ten times greater than sd_1/d_2 where s is the interocular spacing of the observer, d_1 is the closest distance between the image plane and the surface of the optical bending means nearest the image plane (28), and d_2 is the distance between the image plane (28) and the observer, and in which the undulations are formed so that the effective focal length at substantially any location on the surface of the optical bending means is at least approximately 400 mm.

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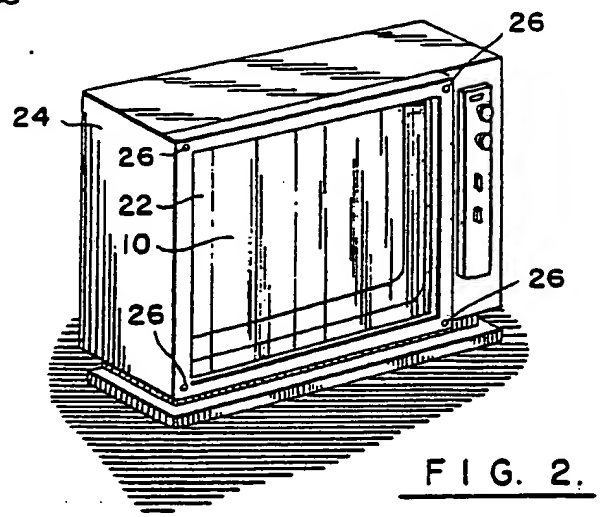

FIG. 2.

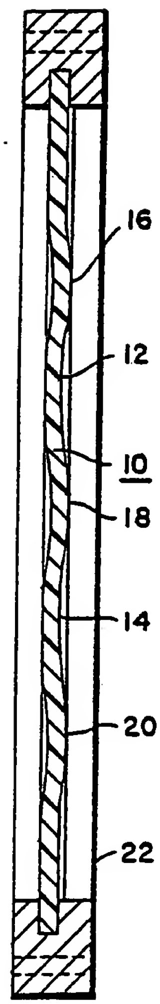

FIG. 1.

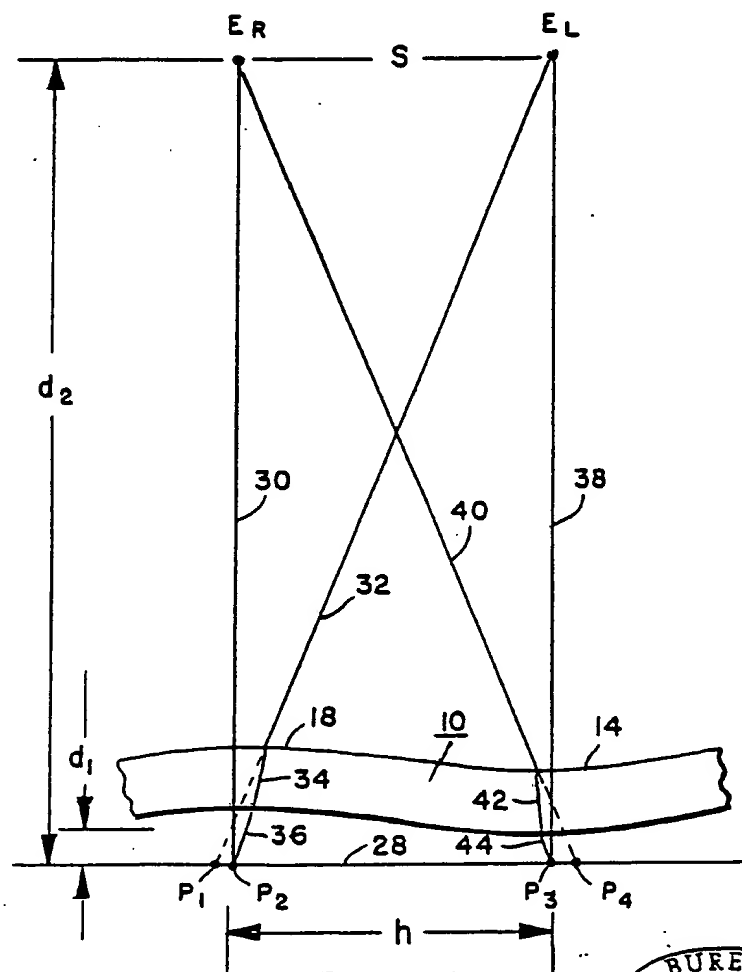

FIG. 3.

INTERNATIONAL SEARCH REPORT

International Application No PCT/US80/01356

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL3 H04N 5/72; G02B 27/22

U.S. CL. 358/250; 350-144

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	358/88, 89, 250, 251, 252 350/144, 160

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	FR, A, 1,101,550, Published 07 October 1955, Robin	1
X	U.S., A, 2,888,855, Published 02 June 1959, Tanaka	1
X	U.S., A, 3,053,135, Published 11, September 1962, Tanaka	1
X	U.S., A, 2,374,566, Published 24, April 1945, Tanaka	1
A	U.S., A, 2,740,954, Published 03, April 1956, Kleefeld	1,2
A	U.S., A, 2,897,488, Published 28, July 1959 Rigney et al.	1,2
A	U.S., A, 2,922,988, Published 26, January 1960, Stephenson	1,2
A	U.S., A, 3,785,720, Published 15, January 1974 Kyryluk	1,2

* Special categories of cited documents: [15]

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"T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention

"X" document of particular relevance

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
10 July 1981	21 JUL 1981
International Searching Authority [1]	**Signature of Authorized Officer [10]**
ISA/US	Edward J. Coles

Form PCT/ISA/210 (second sheet) (October 1977)

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